DEVELOPMENT OF THE RAINFALL RUNOFF RELATIONSHIP FOR KECAU RIVER BY USING HEC-HMS AND IT'S APPLICATION TO TANUM RIVER

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ABSRACT

This study is about flood estimation model for Kecau River and Tanum River in Lipis, Pahang by using Hydrological Modeling System (HEC-HMS). HEC-HMS is tool for analyzing and simulating rainfall and runoff process. HEC-HMS version 4.0 is used in this study to simulate stream flow for Kecau River basin and applied to Tanum River basin since both river have same characteristic. Rainfall and stream flow data that used in this study is from 1999 until 2014. Result of simulation can be generated in summary table, hydrograph and time series table. Correlation coefficient, R^2 is used to measure the performance of the modeling. A model with the R^2 value is nearly to 1.0 is considered as good and satisfactory. During simulation, value of R^2 for station Kg Dusun, Pahang (4320401) in May 1999 is 0.4158 and in January 2010 is 0.8143. The simulated model were fit with the onserved data and show that HEC-HMS are suitable model to predict the stream flow in Tanum River.

ABSTRAK

Kajian ini berkaitan dengan pemodelan anggaran banjir di Sungai Kecau dan Sungai Tanum yang terletak di Lipis, Pahang dengan menggunakan HEC-HMS (Hydrological Modelling System). HEC-HMS adalah alatan penting yang digunakan untuk menganalisa dan membuat simulasi hujan dan proses larian hujan. HEC-HMS versi 4.0 telah digunakan dalam kajian ini untuk membuat aplikasi pergerakan air untuk kawasan tadahan Sungai Kecau dan membuat kalibrasi untuk kawasan tadahan Sungai Tanum memandangkan kedua-dua sungai mempunyai kriteria yang sama. Data hujan dan pergerakan airyang digunakan di dalam kajian ini diambil dari tahun 1999 hingga tahun 2014. Keputusan simulasi ini boleh dilihat di dalam jadual ringkasan, hidrograf dan jadual siri masa. Pekali kolerasi, R^2 digunakan untuk mengukur prestasi pemodelan ini. Pemodelan dengan pekali kolerasi yang menghampiri 1.0 adalah dianggap tepat dan memuaskan. Semasa proses simulasi, nilai R^2 untuk stesen Kg Dusun, Pahang (4320401) untuk May 1999 ialah 0.4158 dan untuk January 2010 ialah 0.8143. Simulasi pemodelan adalah tepat dengan data yang diperhatikan dan ianya menunjukkan bahawa HEC-HMS adalah pemodelan yang sesuai digunakan untuk meramal aliran sungai di Sungai Tanum.

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LIST OF SYMBOLS

q_t	Discharge at time
q_o	Discharge at time, t=0
K	Fitting coefficient
Q	Calculated flowrate
A	Area of catchment involve
I	Design rainfall intensity
C	Runoff coefficient
t_r	Effective rainfall duration
q_p	Peak direct runoff rate
t_1	Basin lag time
q_{pR}	peak discharge per unit of watershed area
t_{1R}	basin lag
t_b	Base time
A_1	Basin area
C	Conversion constant
Cp	UH peaking coefficient.
S	Potential storage
CN	Curve number
Tc	Time of concentration
L	Lag
a_x	Incremental of watershed area
Q_x	Runoff from area

T_{tx}	Travel time
A_2	Total area of the watershed above the references point
Q_a	Total runoff

LIST OF ABBREVIATIONS

HEC-HMS	Hydologic Engineering Center Hydrologic Modelling System
JPS	Jabatan Pengairan dan Saliran
UH	Unit Hydrograph
SCS	Soil Conservation Service
JUPEM	Jabatan Ukur dan Pemetaan

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Water is an important natural resource for all creatures on this earth. Humans, animals and plants need water in their daily life. Without water, living thing can not only survive, but also the development and the industry could not operate. This is because, water play a big part in the growth of the community as a permanent water supply system is a prerequisite to building a permanent community. Unlike other raw materials, there are no materials that can replace the water because it cannot be created or replaced. There are a few natural water sources such as rivers, ground water, dew, snow and rain. However, too rapid technological advances today allow re-use of rain water in an effort to alleviate the shortage of clean water supply and water pollution issues.

Hydrologic cycle is a conceptual model that describes the storage and movement of water between the biosphere, atmosphere, lithosphere, and the hydrosphere Water on our planet can be stored in any one of the following major reservoirs: atmosphere, oceans, lakes, rivers, soils, glaciers, snowfields, and groundwater. Water moves from one reservoir to another by way of processes like evaporation, condensation, precipitation, deposition, runoff, infiltration, sublimation, transpiration, melting, and groundwater flow.

Basically, river flooding occurs because of the incidences of the heavy rainfall and the resultant large concentration of runoff, which can exceed the capacity of the river. Commonly, the major problem in Malaysia due to hydrological problem is flooding. Due to the flooding problem, there are many software have been created to analyze and stimulate rainfall and runoff process. In this research, Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) is used to stimulate rainfall-runoff model. The relationship between rainfall and runoff by producing hydrograph can be obtained by using this software.

Since Kecau River is near to Tanum River, the watershed characteristic is almost similar. So, calibrated hydrological model of Kecau River will be used to predict stream flow for Tanum River.

1.2 PROBLEM STATEMENT

Flooding is one of the regular natural disaster due to this factor and flooding is becoming a common phenomenon in Malaysia. Basically, river flooding occurs because of the incidence of the heavy rainfall and the resultant large concentration of runoff, which can exceed th capacity of the river. The rivers that contribute flood problem in Pahang are Kecau River and Tanum River.

Kecau River and Tanum River are stream in the region of Pahang, the country of Malaysia. Flooding risk at Kecau River is extremely high and medium at Tanum River. Modeling system (HEC-HMS) is designed to analyze the rainfall-runoff at these both rivers.

1.3 OBJECTIVES

The objectives of this study are:

i. To develop rainfall-runoff model for Kecau River
ii. To apply Clark Unit Hydrograph method for determining the rainfall-runoff relationship in Kecau River and Tanum River
iii. To apply a calibrated rainfall-runoff of Kecau River to Tanum River (un-gauge stream flow)

1.4 SCOPE OF STUDY

The study was carried out on two catchment area. The catchment used in this study are Kecau River and Tanum River in Pahang, Malaysia. Kecau River have 61.5km long with average elevation 76m above sea level while Tanum River have 12.5km long with average elevation 91m above sea level. The hydrology data are analyzed by using HEC-HMS that obtain from rainfall data and flow rate from the runoff. By analyzed this data using HEC-HMS, we can predict the discharge and determine the rainfall-runoff relationship for Kecau River and Tanum River in certain period of time.

In addition, this study includes data collection work. Specific required data needs from these rivers. For data collection I need to do site visit to Jabatan Pengairan dan Saliran (JPS) at Ampang. The second part deal with data analyzing which is analyze the data by comparing the rainfall-runoff for these two rivers.

1.5 SIGNIFICANCE OF STUDY

From this research, the rainfall-runoff relationship can be obtained from using Hydrologic Modeling System (HEC-HMS). It is important to do this research because the data from this research is effective to use in order to solve and prevent flood in the catchment area with or without gauge.

CHAPTER 2

LITERATURE REVIEW

2.1 HYDROLOGY

Hydrology is a fascinating discipline of knowledge. It is concerned with water on, under and above the land surface. Scientific and engineering hydrology covers a broad field of interdisciplinary subjects that may be approached from various perspectives, including those of the geologist, chemists, civil engineers, environmental engineers, as well as hydrologists. U.S National Research Council had interpreted hydrology is the science that treats the water of the Earth their occurrence, circulation, and distribution, their chemical and physical properties, and their reaction with the environment including the relation to living things. The domain of hydrology embraces the full life history of water on earth.

2.1.1 Hydrologic Cycle

Water does not remain locked up in the ocean, icecaps, groundwater system or the atmosphere. Instead, water is continually moving from one reservoir to another. This movement of water is called hydrologic cycle. This phenomenon has even been noticed in the early days of mankind.

The main link in the water cycle in nature is exchange between the oceans and land, which includes not only quantitative renewal, but qualitative restoration as well. All types of nature waters are renewed annually, but the rates of renewal differ sharply. As for general description for hydrologic cycle, it is the continuous, unsteady circulation of the water resources from the atmosphere to under the land surface by various processes, back to atmosphere (Walesh, 1989). It consist of various unsteady processes occurring either in the atmosphere or beneath the earth's surfaces and illustrated by **Figure 2.1** below.

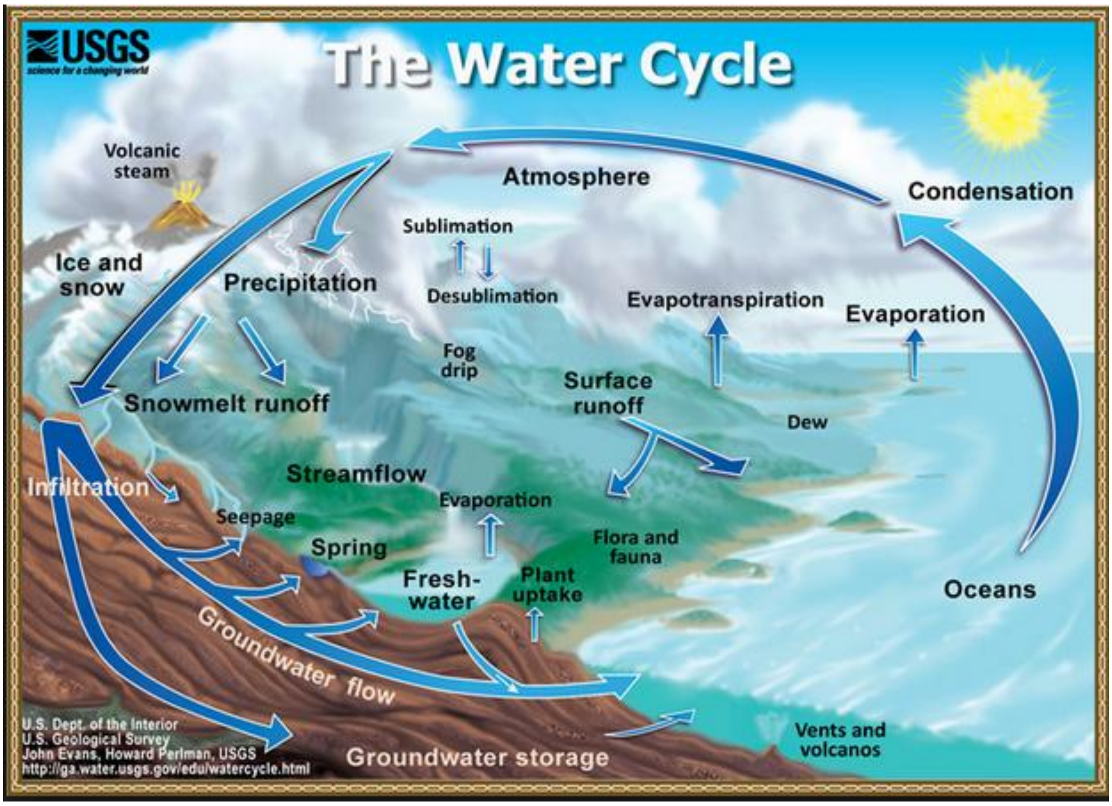

Figure 2.1: Hydrologic cycle

Source: USGS water science school

The hydrological processes involved in the cycle. Energy from the sun results in evaporation of water from ocean and land surfaces and also causes differential heating and resultant movement of air masses. Water vapor is transported with the air masses and under the right conditions becomes precipitation. Evaporation from oceans is primary source of atmospheric vapor for precipitation, but evaporation from soil, stream, lakes, and transpiration from vegetation also contribute. Precipitation runoff from the land becomes streamflow. Soil moisture replenishment, groundwater storage and subsurfaces flow occur as a result of water infiltrating into the ground while stream and groundwater flow convey water back to the oceans. Overall, the hydrologic processes by which water moves through the hydrologic cycle includes atmospheric movement of air masses, precipitation, evaporation, transpiration, infiltration, percolation, groundwater flow, surfaces runoff and streamflow.

2.1.2 Hydrological Characteristics

Hydrological characteristic refer to rainfall distribution, runoff distribution and peak discharge at a particular location along the course of river or stream (Sudmeyer, R.A., 2004). One of the important graph to determine hydrological characteristic of the river or stream is hydrograph. Annual hydrograph can predict the changes in the flow of water over the year at a certain location (RAMP, 2007). It shows all variations of the flow and periods of high and low flows while hydrometric data refer to data collection of that flow.

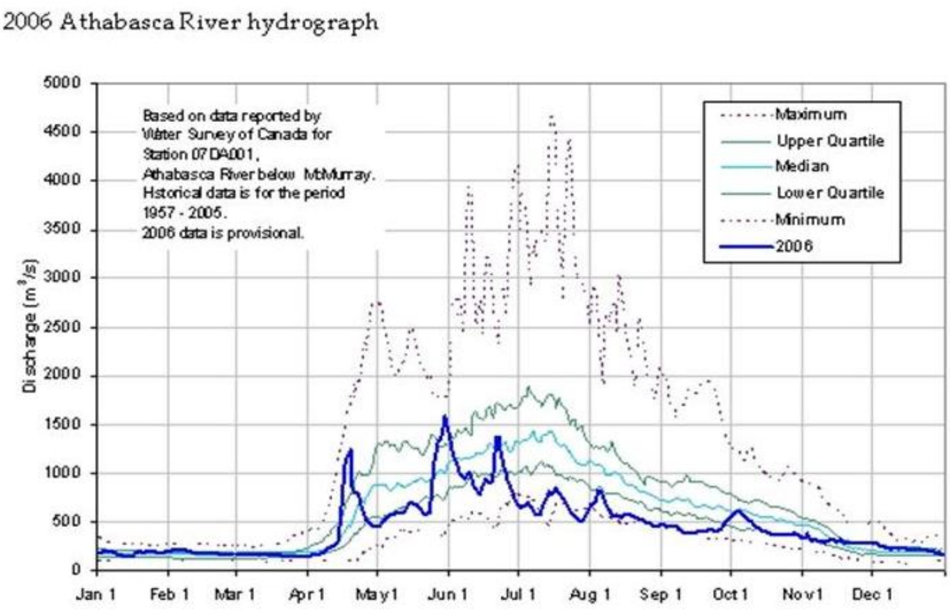

Figure 2.2: Example of a hydrograph for Athabasca River

Source: RAMP, 2007

There are three important parts of hydrograph which are crest segment (peak flow), rising limb and falling limb (recession curve). These parts are measured at a specific point in certain river and typically time variation (Strandhagen et al., 2006). Rising limb represents the increasing of stream flow rate while peak flow shows the maximum flow rate that occur and falling limb is where the stream flow rate is decreasing.

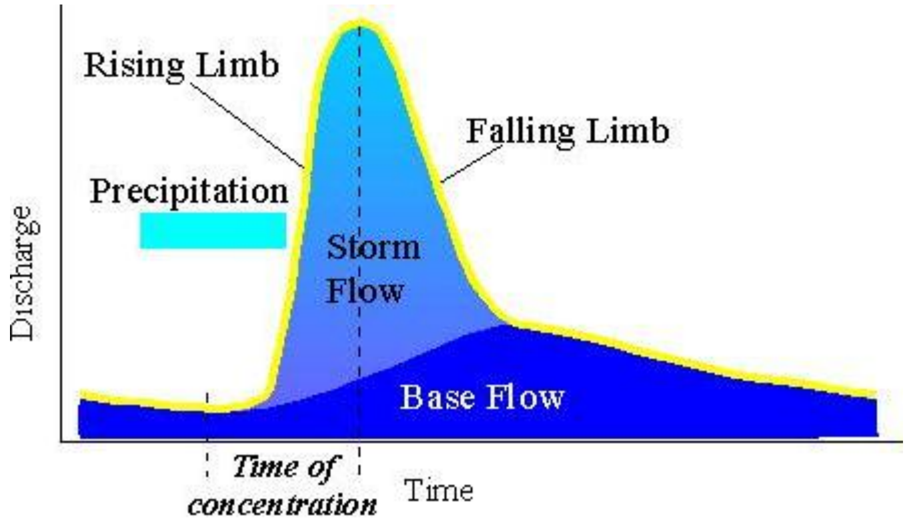

Figure 2.3: Charecteristic of hydrograph

Source: NRCCA study resources

Some of the hydrological indicators used in hydrological characteristic include discharge, maximum flow, minimum flow and median flow. Overall, hydrological characteristic deals with quantitative aspect of the hydrological cycle as well as particular space-time variation of hydrological elements

2.2 RAINFALL AND RUNOFF

Rainfall is known as the main contributor to the generation of surface runoff. Therefore there is a significant and unique relationship between rainfall and surface runoff. By basic principle of hydrologic cycle, when rain falls, the first drops of water are intercepted by the leaves and stems of the vegetation. This is usually referred to as interception storage. Once they reach the ground sirfaces, the water will infiltrate through the soil until it reaches a stages where the rate of rainfall intensity exceeds the infiltration capacity of the soil. The infiltration capacity of soil may vary depending on the soil texture and structure. For instant, soil composed of a high percentage of sand allows water to infiltrate through it quite rapidly because it has large, well connected pore spaces. Soils dominated by clay have low infiltration rates due to their smaller sized pore spaces. However , there is actually less total pore space in a unit volume of coarse, sandy soil than that of soil composed mostly of clay. As a result, sandy soils fill rapidly and commonly generate runoff sooner than clay soils

Apart from rainfall characteristics such as intensity, duration, and distribution, there are other specific factors which have a direct bearing on the occurrence and volume of runoff. The most common factor is the soil type. Due to the variation of runoff production, different studies have been conducted according to particular soil condition. For example, runoff production in blanket peat covered catchment would be rather different than urban area catchment. Blanket peat catchments exhibits flashy regimes, but little is known about the exact nature of runoff production processes within such catchment. In the past, many believed that blanket peatlands were able to attenuate floods and to sustain baseflow in streams and rivers during periods of low precipitation. However, recent studies have demonstrated that intact and degraded blanket peats are indeed extremely productive of runoff and have flashy regimes with little base flow contribution Price. The runoff generation in the area is also associated with the peat soil layering as the deeper layers may be an important overall contributor to runoff .

Another factor that can affect the runoff production is vegetation. An area which is densely covered with vegetation produces less runoff than bare ground while the amount of rain lost to interception storage on the foliage depends on the kind of vegetation and its growth stage. Vegetation has significant effect on the infiltration capacity of the soil. A dense vegetation cover shields the soil from the intense raindrop impact which eventually will cause a breakdown of the soil aggregates as well as soil dispersion with the consequence of driving fine soil particles into the upper soil pores. This results in clogging of the pores, formation of a thin biut dense and compacted layer at the surface which highly reduces the infiltration capacity. This particular effect is often referred as to capping, crusting or sealing. In addition, the roots system as well as organic matter in the soil increases the soil porosity thus allowing more water to infiltrate.

Slope and catchment size also influence the generation of surface runoff. Steep slope in the headwaters drainage basins tend to generate more runoff than the lowland areas. Overall mountain areas tend to receive more precipitation because they force air to be lifted and cooled. On gentle slopes, water may temporarily pond and later infiltrate, but in mountainsides, water tends to move downward more rapidly. Size of catchment may have an effect to the runoff generation in terms of the runoff efficiency (volume of runoff per unit area). The larger the size of catchment, the larger is the time of concentration and the smaller the runoff efficiency.

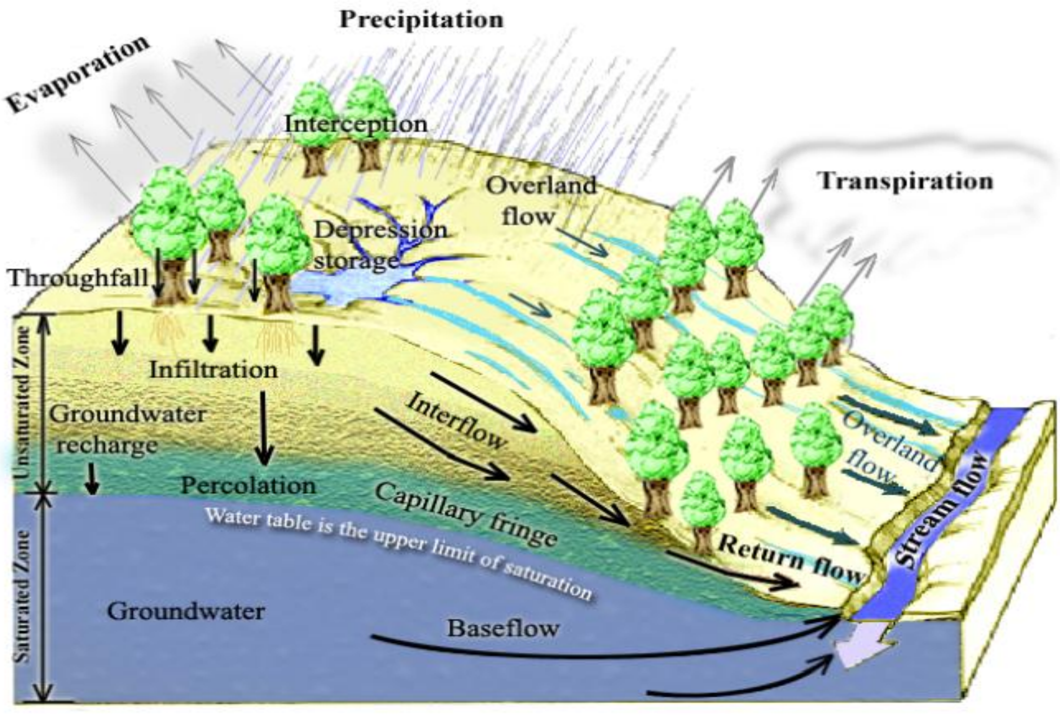

Figure 2.4: Physical processes involve in runoff generation

Source: Hydroviz.org

2.3 PHYSICAL CHARACTERISTIC OF BASIN

2.3.1 Land Use

Various types of physical characteristic of basin give major impact on quality and volume water flow through river and oceans. Land use can be defined as an activity done on the ground or a structure above ground. Land use change is the main cause of human affected on the hydrological system on regional, local and global scale. (B. Bhaduri, 2000). Mostly, it's controlled by increasing of urban area in several scales.

The primary case of land use vary at many scales because of land use by humans. However, the scale of these effects depends on a form of climatic features of the region and land use changes. Negative impacts on human health, loss of wetland habitat and riparian and decreasing of ecological diversity are a few example effect of land use on environmental aspects.

2.3.2 Elevation of the Basin

Elevation of the basin is one of the physical characteristic that affect the time distribution and concentration of discharge from the basin. Elevation of the basin can detect on the topography of the land. There are a few software in hydrological modeling can analysis the network drainage and extraction of the watershed. (N.S. Magesh, K.V. Jitheshlal, N. Chandrasekar and others, 2013).

2.3.3 Slope

Pattern of the watershed drainage depends on the slope of the basin where the surface of every soil is different in each place. It is difficult for rainfall or snow melt to seep into the ground for steep slope while for the shallow and permeable surface, the rainwater become a direct discharge flow. Besides, rate of elevation always change along the main channel and this kind of change can be estimated from the main channel of slope. Hence, more velocity will be generated in the larger slope of basin compared to smaller one.

2.4 RAINFALL AND RUNOFF RELATIONSHIP

2.4.1 Hydrograph separation

Hydrograph separation is a process of separating the major hydrograph components for analysis namely the surface runoff and the baseflow. Surface runoff (rainfall excess) is the water that enters the stream primarily by way overland flow across the ground surface while baseflow is defined as water that enters the streams by way of deep sub-surface flow below the main water table and may include other components such as throughflow and interflow. Several method have been proposed and used for separating the surface runoff and the baseflow but none of them have proven to be more superior as there is no ready basis for distinguishing both components in a stream at any instant. The selection of an appropriate method depends on the type and amount of measured data available, the desired accuracy for the design problem and the effort that the modeler wishes to expend.

Numerous academic explanations have been published in elaborating the separation method. Four types of baseflow separation, which are:

1) Constant-discharge baseflow separation
2) Constant-slope baseflow separation
3) Concave baseflow separation
4) Master depletion curve method